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THE NATURAL RESISTANCE TO DECAY OF SOME EMPIRE TIMBERS

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INTRODUCTION.

DURABILITY may be defined as the ability of any material to resist destructive agencies. The principal destructive agencies to which timber is normally exposed are fungal decay, insect attack and mechanical wear, while in special cases corrosive chemicals such as sulphuric acid or caustic lye may be encountered.

Out of doors in temperate countries fungal decay brings about the destruction of far more timber than any other cause, but in certain tropical countries termites are equally or even more important. Only in special instances, such as in floors exposed to much traffic or in mining timber carrying heavy loads, does mechanical wear bring about the destruction of timber. For this reason the term durability has come to be considered as almost synonymous with resistance to fungal decay and (in the tropics) insect attack. A timber such as beech which under damp conditions is not resistant to fungal attack is, however, very durable as long as it is kept dry or if it is protected by treatment with a wood preservative. Therefore in the following discussion, where a timber is described as not resistant, this does *not* imply that it is not durable if it be kept dry. A timber which is to be used for internal joinery or for the manufacture of furniture does not normally require to have a high resistance to fungal decay.

Where a timber readily absorbs liquids it can be treated with a wood preservative so that its resistance to decay is raised, and often it is more economical to use a non-resistant timber which has been impregnated with a preservative, than it is to use a naturally durable timber.

There is usually some information available about the durability of a timber in its country of origin, this opinion being based on practical experience in its use or on observations of the condition of logs which have been felled and left lying in the forest. In the tropics where termites do so much damage, and where the durability involves resistance to insect attack, no exact information concerning resistance to fungal decay may be available.

It was, therefore, decided to examine the resistance to decay of all the species of timber received at the Forest Products Research

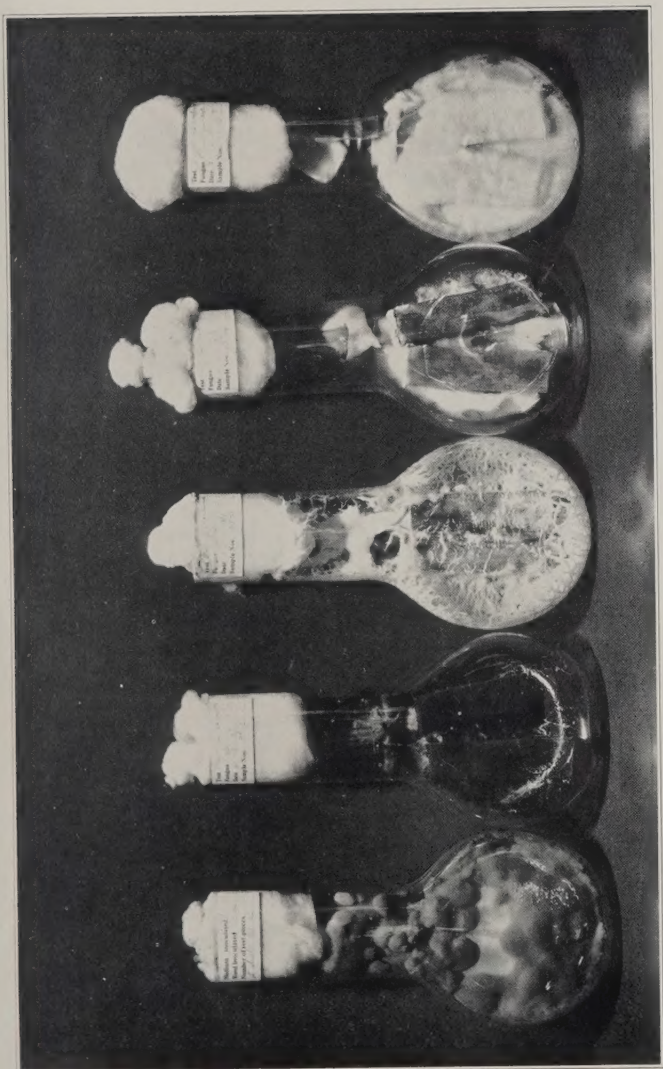
Laboratory, Princes Risborough, at the same time that investigations on their other properties were in progress and when properly authenticated material was available.

METHODS OF TEST.

Two types of test are being carried out, firstly, accelerated laboratory tests, and secondly, larger scale tests in the field and in a special rotting chamber. In the laboratory tests small samples are exposed for a definite period to fungal attack under controlled conditions and their condition is then examined. In the second type of test larger specimens are partially embedded in the soil or placed in contact with decaying wood in a specially humidified chamber and the time taken for them to become so decayed that they can easily be broken by hand, is taken as a measure of their durability.

LABORATORY TESTS.

Small samples are cut and planed to 10 by 2.5 by 1.25 cms. with the long axis parallel to the grain of the wood. Before exposure to the test fungi these must be sterilized, otherwise they will, when moistened, become covered with a growth of mould which will interfere with the growth of the wood-destroying fungi. Some tests have been made to determine whether this sterilization process affects the resistance of the timber to decay, and it was found that while any prolonged heat treatment at 100-105°C. does undoubtedly bring about slight changes in the chemical composition of the wood, the effect of these on the resistance of the wood to decay is very slight and that for *practical* purposes it can be ignored. In any case the treatment is applied to all the species of wood so that the test is at least a comparative one. Drying and sterilization are effected by heating the samples for eighteen hours in an oven at 100°C. The samples are then weighed aseptically on a semi-automatic balance which has been carefully cleaned and of which the pan has been sterilized by wiping with alcohol. Immediately after weighing the samples are introduced into special culture flasks containing the test fungi growing actively on 2 per cent malt agar medium. Ten samples are tested against each species of fungus, two samples being placed in each flask. It has been found that infection of the test blocks is far more certain and more uniform when the wood is placed in this way on active mycelium growing undisturbed on a medium, than when small pieces of fungus are cut out and placed on the test blocks. Although the samples are absolutely dry when they are introduced they soon pick up sufficient moisture from the medium and become moist enough for the fungus to attack them. The flasks containing the samples are kept in an incubator or constant temperature room, maintained at 22°C. They are examined from time to time and



Ceratopetalum apetalum (Coachwood). Laboratory durability test after eight months. Fungi from left to right : *Lenzites striata*, *Coniophora cerebella*, *Lenzites trabea*, *Polystictus versicolor*, *Polystictus sanguineus*.

NATURAL RESISTANCE OF TIMBERS TO DECAY.

when it is observed that the medium is tending to dry out, sterilized water is added to the reservoir in the neck of the flasks.

The usual period of exposure to fungal attack is four months, but in the case of durable timbers the period of test may be extended to eight months to obtain a significant loss in weight. In the earlier tests series of samples were examined after both four and eight months' exposure. After a slight initial lag the rate of loss in weight remains constant till the constituents of the wood are seriously depleted, so that it is possible by dividing by two the figures for the loss in weight after eight months to obtain a rough direct comparison with the figures for a four months' test, but generally speaking it has been found that four months is sufficiently long in order to obtain a fair indication of the timber's resistance to rot.

At the end of this period the blocks are removed from the flasks and any superficial fungous mycelium carefully scraped off without damaging the blocks. A series of flasks containing a non-resistant wood on which vigorous fungus growth has occurred is shown in the illustration. They are examined to see how much softening has taken place, then weighed and after oven drying reweighed. In this way the final dry weight and the final moisture content of the samples are determined.

The final dry weight subtracted from the initial dry weight gives the loss in dry weight due to the fungal attack—this loss when it is calculated as a percentage of the original dry weight gives a useful measure of the amount of decay which has occurred. Perishable timbers exposed to a vigorous wood-destroying fungus may lose over 30 per cent of their weight in four months, and up to 70 per cent in eight months, while a durable timber may lose only 5 per cent or less over the longer period.

At least five or six test fungi are always used. These are chosen from common species which are active wood-destroyers and of economic importance. *Merulius lacrymans*, the dry rot fungus, and *Coniophora cerebella*, the cellar fungus, are always included, since they are the fungi responsible for most of the decay of timber in buildings, and frequently inquiries are received as to whether a timber is resistant to dry rot. Then for tests on hardwoods the following are also used: *Polystictus versicolor*, which is about the most common cause of rotting in hardwoods out of doors in this country, *Lenzites trabea* and *Polystictus sanguineus*, the two last being common wood-rotting forms in most tropical countries; while for tests on coniferous woods *Poria vaillantii*, *Lentinus lepideus* and *Lenzites sepiaria* are used, as well as *Merulius lacrymans* and *Coniophora cerebella*.

RESULTS.

Below are tabulated in alphabetical order the species from the Dominions and Colonies which have been tested recently in the Forest

Products Research Laboratory and a few home-grown species are included for the sake of comparison.

It must be emphasized that with a few exceptions, which are noted, the tests were carried out on samples selected from a single consignment and that it is necessary to carry out tests on samples from several consignments before an absolutely definite opinion can be pronounced on the resistance to decay or other properties of the timber. In certain species, such as western red cedar, the resistance may vary even in different parts of the same tree. On the other hand it has been found that the inherent decay resistance does not vary with rate of growth, etc., to quite the same extent as the mechanical properties; for example it is rare to find a perishable sample of a timber which is normally durable, in the way that one occasionally finds extremely weak samples of normally tough timbers.

The results are based on the average results from ten samples except where figures for both four and eight months are given, when only six samples were tested at each period against each fungus. The average loss in weight caused by the different test fungi is given, but as this is not always based on the same number or species of fungi, much weight should not be attached to it.

In every case the material tested consisted only of heartwood or, where no distinct heartwood is formed, of mature wood. The sapwood of practically all trees is readily attacked by fungi. While the tree is growing the sapwood contains living cells and is usually full of water. For these reasons it has a natural resistance to infection which may even be greater than that of the heartwood, but as soon as the tree is felled these cells die, and as the sapwood begins to dry out it becomes very susceptible to attack by various fungi.

In the last column of the table the timber is classed as very resistant, resistant, moderately resistant, non-resistant or perishable, and these terms may be defined as follows:

Very resistant: Timbers which are highly resistant to fungal attack and which will have a long life when used in situations very favourable for fungal decay, i.e., which can be used in an untreated condition for railway sleepers, poles and fencing posts embedded in the ground.

Resistant: Timbers which are resistant to fungal decay and which have a moderate life (say 10-15 years) when used in an untreated condition for fencing posts, etc. Timbers in this class are suitable for outdoor purposes where they are not in contact with the soil and where they can receive a coat of paint, e.g. for exposed parts of a house, gates, boat-building and so on.

Moderately resistant: Timbers which are liable to decay when exposed to damp conditions for any length of time, and which should, therefore, never be used in contact with the soil without previous preservative treatment, but which can safely be used where there

is only slight risk of occasional brief periods of exposure to damp conditions. Such timbers are suitable for use as ground floor joists in buildings, for flooring and so on.

Non-resistant : Timbers which have little or no resistance to fungal attack under damp conditions, and which must, therefore, either be kept permanently dry in service or protected by thorough treatment with a wood preservative. Such timbers can safely be used in an untreated condition in buildings for carcassing timbers, roofing rafters, joinery, furniture, etc.

Perishable : Timbers which require rapid extraction and careful handling to avoid deterioration, and which are suitable for use only in protected situations or after impregnation with a wood preservative.

FIELD TESTS.

In the field tests small stakes measuring 24 by 2 by 2 in. and sharpened at the end are driven into the ground to a depth of 12 in. These are examined at intervals of six months after insertion and their condition noted. No results are yet available from these tests, but it can be said that the indications are that they will confirm in general the results of the laboratory tests.

FACTORS RESPONSIBLE FOR THE DURABILITY OF TIMBER.

The generally accepted view is that the components of the cell wall substance of all timbers are essentially similar and that variations in the properties of different timbers are due mainly to variations in the proportions of the major components, in the arrangement of wood substance in space and in the amount and nature of the minor components or extractives. There are certain constitutional differences between wood from conifers and that from angiosperms. In general the wood of the latter (hardwoods) is relatively low in cellulose and high in pentosans and few minor components are common to both classes of timber. There is probably also a slight but fundamental difference in chemical composition between hardwoods grown in temperate countries and in the tropics in that the latter tend to be more highly lignified. This is probably the reason why many of the light-coloured tropical hardwoods which are readily attacked by white rot fungi that can decompose lignin, are fairly resistant to the fungi which bring about brown rots and which attack only the cellulose and the associated carbohydrates. Examples of such timbers which resist brown rots but which are attacked by fungi which cause a white rot may be cited : *Maesopsis eminii*, *Ochroma* sp., *Olea hochstetteri*, *Scotellia coriacea*, *Terminalia procera*.

The principal factor responsible for the durability of the heartwood of most timbers is the presence in them of certain extractives toxic to wood-destroying fungi, which are formed during the transformation

Botanical Name	Common Name	Country of origin	Period of Test (months)	Loss in weight per cent caused by test fungi					Average for fungi tested	Class of Resistance
				<i>Merulius lacrymans</i>	<i>Coniophora cerebella</i>	<i>Polystictus versicolor</i>	<i>Polystictus sanguineus</i>	<i>Lenzites trabea</i>		
<i>Acer pseudoplatanus</i> L.	Sycamore	England	4 8	26.0 42.6	20.8 33.1	39.8 50.0		22.2 29.3	27.4 38.8	Perishable
<i>Alstonia congensis</i> Engl.	Mufua	Uganda	4 8	4.9	24.8 36.4	15.8 46.4		21.5 38.3		Perishable
<i>Bakiaea pluripecta</i> Harms.	Rhodesian "Teak"	Rhodesia	8	5.2	4.6	4.5	4.4	5.9	4.9	Very resistant
<i>Calophyllum brasiliense</i> var. <i>rekoi</i> Standl.	Santa Maria	British Honduras	4 8	Nil 10.2	6.1 15.3	2.0 9.8			8.4	Resistant
<i>Celtis</i> (?) <i>sagarezi</i> Engl.	Celtis	Nigeria	8	40.1	39.0	42.6	47.3	36.1	41.2	Perishable
<i>Ceratopetalum aptatum</i> D. Don	Coachwood	Australia	8	31.1	29.2	47.9	25.3	46.9	36.1	Not resistant
<i>Chlorophora excelsa</i> Benth. et Hook. (Male, female and dead trees tested)	Iroko	Uganda	8	Nil	Nil	Negligible	Nil	Negligible	Nil	Very resistant
<i>Cistanthera papaverifera</i> A. Chev.	Otutu Danta	Nigeria Gold Coast	4 4	7.2	8.5	11.2 24.0				Moderately resistant
<i>Cycladicus gabonensis</i> Harms.	Okan	Nigeria	4	Nil	Nil	Negligible	Nil		Negligible	Very resistant
<i>Diospyros insculpta</i> Hutch. & Dalz.	Uhu	Nigeria	4	2.1	2.7	4.5	3.6	2.6	3.1	Resistant
<i>Dipterocarpus laudii</i> Korth.	Keruing	Malaya	8	13.5	36.3	11.0		18.2	19.8	Not resistant
<i>Dipterocarpus tuberculatus</i> Roxb.	Eng	Burma	4 8	Negligible Negligible	Negligible 6.6	5.8	6.2 12.9	Negligible	2.4 4.9	Moderately resistant
<i>Dipterocarpus zeylanicus</i> Thw.	Ceylon Gurjun	Ceylon	4 8	1.4 5.6	6.8 19.7	3.0 12.1		1.6 5.9	3.2 10.8	Moderately resistant

N.B.—Figures in black type represent the results of eight months' tests.

Botanical Name	Common Name	Country of origin	Period of Test (months)	Loss in weight per cent caused by test fungi						Average for fungi tested	Class of Resistance
				<i>Merulius lacrymans</i>	<i>Coniophora cerebella</i>	<i>Polystictus versicolor</i>	<i>Polystictus sanguineus</i>	<i>Lenzites trabea</i>			
<i>Dryobalanops aromatica</i> Gaertn. f. . .	Kapur, Borneo Camphorwood.	Malaya . .	8	4.5	6.3	2.2		1.4	3.4	Very resistant	
<i>Endandrophragma angolense</i> C. DC. .	Mukusi . . .	Uganda . .	8	10.7	25.3	54.3		17.3	26.9	Not resistant	
<i>Endandrophragma utile</i> Sprague . .	Mufumbi . . .	Uganda . .	8	14.1	13.0	4.8		1.3	9.3	Moderately resistant	
<i>Eperua sulcata</i> Aubl.	Wallaba . . .	British Guiana .	8	Negligible	2.4	Negligible		2.3	Negligible	Very resistant	
<i>Eucalyptus microcarpa</i> F. von Muell	Tallowwood . .	Australia . .	4	5.5 (?)	4.3 (?)	4.4 (?)	6.6 (?)	5.8 (?)		Resistant, probably loss in weight due to loss of extractives	
<i>Eucalyptus</i> (?) <i>obliqua</i> L'Hér. . .	Stringybark, Tasmanian Oak.	Australia . .	8	5.9	6.5	8.9				Moderately resistant	
<i>Fagus sylvatica</i> L.	Beech	England . .	4	26.2	31.0	37.7		38.6	33.4	Perishable	
<i>Gossweilerodendron balsamiferum</i> Hartus	Agba	Nigeria . .	4	NH	NH	Negligible		NH	Negligible	Resistant	
<i>Guarea cedrata</i> (A. Chev.) Pell. . .	Scented Guarea . .	Nigeria . .	8	13.9		20.2				Not resistant	
<i>Guarea thompsonii</i> Sprague & Hutch.	Guarea	Nigeria . .	8			7.2				Moderately resistant	
<i>Khaya anthabacca</i> C. DC.	Munyama, African Mahogany.	Uganda . .	4 8	7.0 15.6	12.9 25.1	8.6 17.3			9.5 17.3	Not resistant	
<i>Koompassia malaccensis</i> Malag. . .	Kempas	Malaya . .	8	6.8	8.6	4.4		9.7	7.4	Moderately resistant	
<i>Lonchocarpus castilloi</i> Standl. . .	Black Cabbage Bark	British Honduras	4	NH	NH	NH	NH	NH	NH	Very resistant	

N.B.—Figures in black type represent the results of eight months' tests.

ANGIOSPERMS—Continued.

Botanical Name	Common Name	Country of origin	Period of Test (months)	Loss in weight per cent caused by test fungi					Average for fungi tested	Class of Resistance
				<i>Merulius lacrymans</i>	<i>Coniophora cerebella</i>	<i>Polystictus versicolor</i>	<i>Polystictus sanguineus</i>	<i>Leucites trabeca</i>		
<i>Mansonia altissima</i> A. Chev.	Mansonia	Nigeria	8	Nil	12.6	23.2	Nil	Nil	Nil	Very resistant
<i>Macaranga emini</i> Engl.	Musil	Uganda	4 8	8.0 19.5	23.7	68.5	19.4 30.3	13.3 33.0	13.3 33.0	Not resistant
<i>Mora acedba</i> Benth.	Black Mora	Trinidad	4 8	2.0 6.2	11.8 23.3	18.0 41.3	10.5 20.4	10.8 25.0	10.8 25.0	Not resistant
" " " "	White Mora	"	4 8	2.0 4.1	2.7 16.2	6.2 32.6	6.1 9.6	6.0 15.6	6.0 15.6	Not resistant
" " " "	Red Mora	"	4 8	3.7 3.9	4.8 9.3	6.3 13.9	4.3 5.5	4.8 8.1	4.8 8.1	Moderately resistant?
" " " "	British Guiana Mora	British Guiana	4 8	2.2 2.8	4.6 8.3	4.4 7.3	3.7 15.0	3.8 8.3	3.8 8.3	Resistant
<i>Ochroma</i> sp.	Balsa	South America	4	5.6	4.7	43.1	33.6	13.7	20.1	Not resistant
<i>Ochroma usambarensis</i> Endl.	East African Camphorwood.	Uganda	4	2.2	3.5	1.7	2.2	1.6	2.2	Very resistant
<i>Olea hardstedtii</i> Baker	East African Olive	Kenya	4	Negligible	Negligible	11.2	5.3	Negligible	Negligible	Moderately resistant
<i>Pithecyne porphyrocardia</i> Griseb.	Purpleheart	Trinidad	4 8	Negligible Negligible	2.1 6.3	Negligible Negligible	Negligible Negligible	Negligible Negligible	Negligible Negligible	Very resistant
<i>Phenacarpus angolensis</i> DC.	Mulugu	Tanganyika	4	Negligible	Negligible	2.1	2.0	Negligible	Negligible	Very resistant
<i>Quercus robur</i> L.	English Oak	England	4 8	1.4 5.7	4.0 11.2	3.7 (4.2)				Resistant

N.B.—Figures in black type represent the results of eight months' tests.

Botanical Name	Common Name	Country of origin	Period of Test (months)	Loss in weight per cent caused by test fungi					Average for fungi tested	Class of Resistance
				<i>Merulius lacrymans</i>	<i>Coniophora cerebella</i>	<i>Polystictus versicolor</i>	<i>Polystictus sanguineus</i>	<i>Lenzites trabea</i>		
<i>Succowia albertiana</i> De Wild.	Opepe	Nigeria	8	Negligible	Negligible	3.0	2.5	Negligible	Negligible	Very resistant
<i>Sedella coriacea</i> A. Chev.	Odoko	Nigeria	4	2.2	Negligible	22.2	23.4	2.3	10.0	Not resistant
<i>Symphonia globifera</i> L. f.	Waika Chevstick	British Honduras	4	Nil	Nil	Nil	Nil	Nil	Nil	Very resistant
<i>Terminalia ivorensis</i> A. Chev.	Black Afara, Idigbo	Nigeria	8	Negligible	Negligible	4.0	5.8	Nil		Resistant
<i>Terminalia oborata</i> (R. et P.) Steud. var. (Honduras).	Nargusta	British Honduras	4	Negligible	2.7	3.8	2.3	Negligible	1.8	Resistant
<i>Terminalia oborata</i> (R. et P.) Steud. var. (Trinidad).	White Olivier	Trinidad	8	Negligible	2.9	4.4	15.5	2.1	5.0	Resistant
<i>Terminalia procera</i> Roxb.	White Bombay	India (Andamans).	4	Negligible	Negligible	13.1	11.6	Negligible	5.3	Not resistant
<i>Terminalia superba</i> Engl. & Diels	White Afara	Nigeria	4	3.3	3.0	24.7	30.6		15.4	Not resistant
<i>Triplachiton sclerocylon</i> K. Schum.	Ochehe	Nigeria	8	6.5	6.4	8.1	27.0	9.1	7.5	Not resistant
				26.4	19.4	28.0		15.8	22.4	
<i>Ulmus americana</i> L.	American Elm	North America	4	28.5	8.5	29.5	39.1	36.7	28.5	Perishable
<i>Ulmus thomasi</i> Sarg. (T. racemosa Thomas).	Rock Elm	Canada	4	8.6		17.4	7.9			Moderately resistant to not resistant
<i>Ulmus procera</i> Salisb.	English Elm	England	4	2.4	Negligible	22.4	17.2	5.8	12.0	Resistant to not resistant
<i>Virola merendonis</i> Pitt.	Banak	British Honduras	8	53.5	41.2	58.4	70.6	52.0	55.1	Perishable
<i>Yochysia hondurensis</i> Sprague	Yemerli	British Honduras	8	45.7	35.4	45.9	32.0	55.7	42.9	Perishable

N.B.—Figures in black type represent the results of eight months' tests.

of sapwood into heartwood. These substances may be water-soluble, as has been shown to be the case in western red cedar where they are phenolic in nature, and in oak where they are tannins, or they may be substances which can be extracted only in certain solvents such as alcohol and benzene, such as an ethereal oil in *Thujaopsidolabrata*.

There is no direct relationship between specific gravity (density) of timbers and their durability, though it is true to say that most of the very heavy timbers tend to be durable and that most of the light ones are readily attacked, but there are many exceptions—western red cedar, for instance, being very light in weight yet resistant to decay. It is obvious, of course, that the more dense a wood is, the more actual wood substance there is, and the longer it must take a wood-destroying organism to destroy it all. A very dense wood also contains less air than a light one, and under very wet conditions may become practically waterlogged and, therefore, immune to attack by wood-rotting fungi, which all require a certain amount of air.

Within a single species it is probably correct to say that the higher the density the more durable the timber, a slow-grown dense sample of Douglas fir, for instance, being more durable than a light, quickly-grown sample of the same species.

Colour is some guide to the probable resistance to decay of an unknown timber. Speaking very generally, one may say that the darker that a timber is the more likely it is to be resistant. Very few light-coloured woods are highly resistant, and it is those species which have well-marked heartwood of a pronounced nature that tend to be the more resistant.

PRACTICAL VALUE OF TESTS ON NATURAL RESISTANCE.

It is not claimed that it will ever be possible to predict from laboratory tests the exact life of any timber used in a particular situation, but since the results of the laboratory tests on timbers, the resistance of which is already well known, agree fairly closely with the results from service data, we may place some reliance on the laboratory tests which we have made on new and little known species.

When deciding whether a timber is sufficiently resistant to be used for any specified purpose slight differences in resistance are usually of no importance. Within the limits of single species there is usually so much variation that it is futile to attempt any very precise classification. In order that a timber can safely be used in an untreated condition in contact with damp soil it must be resistant or very resistant to rot, and if from our tests it is possible to classify the timbers broadly into four or five groups, that is usually sufficient. For instance, any ordinary commercial softwood should give good

service as building timber in temperate countries, provided that the construction of the building is good, and discussions as to the relative durability of red and white deal are really pointless: under damp conditions both will decay, under dry conditions neither will. In all commercial consignments of a timber such as red deal a large proportion of the pieces contain sapwood which has a very low resistance to decay, but which can quite safely be used in a properly built house.

In this article only resistance to fungal decay has been considered, but where it is necessary to consider also the risk of insect attack the question of the presence of sapwood assumes increased importance, since even under dry conditions certain insects such as *Anobium* and *Lyctus* can attack dry sapwood, the latter requiring, however, that the sapwood should contain sufficient starch.

SUMMARY.

- (1) A description is given of a laboratory method of testing the resistance to decay of timbers—small selected samples are exposed to fungal attack under controlled conditions for four or eight months, and the amount of attack estimated from the percentage loss in dry weight caused by the test fungi.
- (2) The results obtained with a number of species of Empire and home-grown timbers are tabulated and the timbers are classified on a basis of their resistance to decay.
- (3) The nature of decay resistance and the importance of the soluble extractives in increasing the resistance of a timber to fungal decay are discussed.

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